POWER IN ALBERTA

WATER, COAL AND NATURAL GAS

Commission of Conservation
Canada

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AND
NATURAL GAS

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BY

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Power in Alberta—Water, Coal and Natural Gas*

POWER has been defined as the "substitution of mechanical energy for human energy, of mechanical work for human labour." As a result of the utilization of power, civilized nations expend enormously more energy than the combined muscular power of their inhabitants and their beasts of burden. Sir Dugald Clerk has estimated that the factories of the world, including electric lighting and street railways, use 75,000,000 horse-power; the railways of the world, 21,000,000, and the shipping of the world, 24,000,000; or a total of 120,000,000 horse-power. Fairgrieve, in his *Geography and World Power*, says that "the power of Greece, whereby she achieved such great things in all directions of human progress, was largely based upon the work done by the servile class. On the average, each Greek freeman, each Greek family, had five helots, whom we think of not at all when we speak of the Greeks, and yet these were the men who supplied a great part of the Greek energy."

Distribution of Power

Of the 75,000,000 horse-power used in the factories and general industrial and municipal activities of the world, about 13,000,000 is used in the United Kingdom, about 29,000,000 is used in the United States, and 6,000,000 in the British Dominions and Dependencies.

The work accomplished annually in the industries alone of the United States, is, therefore, equivalent to the labour of 580,000,000 slaves, and each family in the United Kingdom has, in the industries, nearly 30 serfs to "supply energy, requiring no food, and feeling nothing of the wear and tear and hopelessness of a servile life."

Having demonstrated the enormous importance of power, the next step is the examination of the particular problem under considereration, namely, power in the province of Alberta.

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* It should be emphasized that this paper is only a general review of this important subject. It applies to the province of Alberta only and, therefore, some of the conclusions might not apply with equal force to other provinces of Canada.

It should also be emphasized that this paper refers only to the production of power on a *wholesale* scale.

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WATER-POWER

Factors Governing Water-power

Water-power, with its numerous advantages, is naturally first in order of consideration. On the map of Alberta (see pp. 16 and 17) the water-powers of over 5,000 twenty-four-hour-low-water power are shown by a large dot, the figures indicating the minimum in thousands of horse-power. Probably the first impression gained on examining the map will be that the amounts of power indicated are much too low, such impression being, in part, based upon the exaggerated statements that have been made from time to time. It may also be partly due to the impression gained, say, by the traveller who, from the railway train in summer sees large volumes of water flowing down the beautiful rivers of Alberta. The traveller is not aware, or forgets, that the low-water season in the western rivers is not in the driest summer weather when the glaciers and snow-fields are swelling their volume, but in the coldest winter, when frost seals the ice and snow-fields and the volume is practically dependent upon the springs that feed the streams.

Another important consideration is the height of the falls that are available. This is a geological question. The Rocky mountains are, in large part, composed of limestone, with sandstone and shales in some valleys in the eastern portion. The tendency of a river flowing over such rocks is to reduce its bed to a nearly uniform gradient, hence the few falls of considerable height. On the other hand, high dams to create high heads are, in most instances, prohibited by the heavy cost, and, in the case of several important streams, the presence of railways debars such constructions.

Before considering the economic phase of the question, the principal water-powers in Alberta of over 5,000 minimum-twenty-four-hour power should be noted. They are as follows:

WATER POWERS IN ALBERTA HAVING AN ESTIMATED MINIMUM CAPACITY OF 5,000 H.P. OR OVER

Site	Head, feet	Estimated minimum h.p.	Distance from principal market and cognate data*
Bow River:†			
Radnor	44	8,000	25 miles from Calgary.
Ghost	50	9,000	30 miles from Calgary.
Mission	47	8,000	35 miles from Calgary.
Bow Fort	66	11,000	38 miles from Calgary.
Horseshoe fall	70	12,000	42 miles from Calgary.‡
Kananaskis fall	70	12,000	45 miles from Calgary.‡

Site	Head, feet	Estimated minimum h.p.	Distance from principal market and cognate data.*
Elbow river:			
Near Cañon creek............	225	5,000	30 miles from Calgary. Other scheme using head of 500 feet also possible.
North Saskatchewan river:†			
Rocky rapid..................	85	28,000	65 miles from Edmonton. Would require a dam 85 feet high.
Athabaska river:			
5 m. above Mountain rapid....	15	7,000	220 miles from Edmonton.
Rock rapid....................	12	5,000	220 miles from Edmonton.
Crooked rapid................	13	6,000	220 miles from Edmonton.
Long rapid....................	28	12,000	220 miles from Edmonton.
Middle rapid.................	20	9,000	215 miles from Edmonton.
Boiler rapid..................	25	11,000	215 miles from Edmonton.
Grand rapid...................	54	22,000	200 miles from Edmonton.
Pelican rapid and rapid above..	17	7,000	165 miles from Edmonton.
Baptiste power...............	80	12,000	150 miles from Edmonton.
7 miles above Baptiste river....	42	6,000	150 miles from Edmonton.
Peace river:			
Vermilion fall and rapid.......	26	20,000	340 miles from Edmonton.
Peace Cañon rapids**.........	225	94,000	380 miles from Edmonton. Would require a flume or conduit about 9 miles long, if developed at one site.
Slave river:			
Lower Fort Smith Rapids power	48	128,000	450 miles from Edmonton.
Upper Fort Smith Rapids power	69	184,000	445 miles from Edmonton.

* The mileages given in this column are air-line distances and, in most cases, are only given to the nearest five miles. As a rule, the transmission line would be at least 10 per cent longer.

† The figures for the North Saskatchewan and Bow rivers are for regulated flow. For the Bow, the minimum, with unregulated flow, is less than one-half the figures given.

‡ Calgary Power Co.'s hydro-electric plant.

** In British Columbia.

The total low-water potentiality of the water-powers of Alberta is estimated at 450,000 h.p. The developed water-power aggregates 33,000 h.p.

It should be noted here that the figures for the powers on the Athabaska, Peace, and Slave rivers, given in our report on *Water Powers of Manitoba, Saskatchewan, and Alberta*, are for the open season only, namely, from May to November. Accurate data respecting the minimum flow of these rivers are not obtainable, but available information indicates that the minimum in winter is about one-third of the open-season minimum, and the figures quoted above are based upon that assumption.

Limited Water-Power Resources

The foregoing brief review of the larger water-powers of Alberta does not indicate great resources in the vicinity of the well-settled portions of the province, assuming that the demand for power is uniform throughout the

twelve months of the year. It is nceessary, therefore, to consider measures to supplement or to replace power from water.

The North Saskatchewan, South Saskatchewan, and Bow usually reach the highest stages in the latter part of June, and the lowest stages are usually reached in the latter part of December. In the average year, the low-water period extends from December to April, both inclusive, and, if Alberta's water-powers are to be utilized to anything approaching their capacity, measures must be taken to supply the deficiency during the low-water season.

During the period 1911–16, the maximum discharge of the North Saskatchewan at Edmonton was 186,560 cubic feet per second on June 28,1915, and the minimum was 650 c.f.s. on December 25, 1913, or, in other words, the high-water flow was 286 times the low-water flow. During the same period the high-water discharge of the South Saskatchewan at Medicine Hat on June 28, 1915–84,700 c.f.s.–was 110 times the low-water discharge on December 27, 1911–772 c.f.s. During 1910-16 the high-water discharge of the Bow river at Calgary,on June 26, 1915,–28, 130 c.f.s—was 48 times the low-water discharge on December 27, 1912—580 c.f.s.

With the exception of the Niagara and the St. Lawrence, there is probably no large river in Canada which is not very materially affected by occasional extreme low-water stages. If, therefore, our streams are to be developed to utilize their potential value as producers of water-power, they can only be fully utilized by providing auxiliary steam, gas, or other power-generating equipment.

Possibilities of Storage

The most obvious method of supplementing the low-water flow is, of course, by provision of storage. Unfortunately, the streams of Alberta do not drain large lakes, nor, in most instances, is it possible to construct large artificial reservoirs except at heavy cost. The largest lake in the Rockies is lake Minnewanka, on the Bow. It has an area of six square miles and the present dam provides a total storage of 58,080 acre-feet. Bow lake and Spray lake are also available for additional storage aggregating 198,400 acre-feet.

With Alberta's enormous coal resources, however, the deficient power during the low-water months could readily be supplied by auxiliary steam plants. Such plants could also take care of the peaks of the loads.

If such auxiliary stations are only required for a few months in the year, it may be advisable to construct them at low first cost, even at a sacrifice in economy. If operated to cut down the peak

load, however, or to prevent interruptions of service, economy of operation is more important.

Steam-power *vs.* Water-power

In the foregoing review, attention has been devoted solely to water-power and its utilization.

There is a fairly general popular belief that water-power is *inherently* cheaper than steam-power. As a matter of fact, their relative costs are dependent upon a number of considerations, and, in many instances, steam-power is cheaper than water-power, particularly since 1914, owing to the altered conditions created by the war.

As compared with steam-power, water-power has the following advantages:

(1) Cost of operation is usually much lower.

(2) Very few attendants are required in the plant. No fuel except for heating the building.

The disadvantages are:

(1) Usually the cost of development and installation is much higher than with steam-power.

(2) The situation of the water-power plant is fixed by nature. This lack of elasticity necessitates, on the average, a longer transmission line to transmit the electric energy to the user.

(3) The service is less reliable owing to the possibility of lack of power due to unusually low water.

Effect of Steam Turbine on Development

During recent years, largely owing to the introduction of the steam turbine, the capital costs of modern high powered steam plants and of many hydro-electric developments are coming close together, and many engineers predict that, at an early date, steam-electric power will be produced at less expense, other things being equal, than hydro-electric energy. Formerly, steam plants consumed 30 to 35 lbs. of ~~coal~~ steam per h.p.-hour; now, modern plants use 9 to 9½ lbs. In 1915, a modern steam turbine of large size, using units of 10,000 to 20,000 kilowatts (13,300 to 26,600 horse-power) rating could be constructed for from $50 to $60 per kilowatt ($37 to $45 per horse-power) of maximum capacity as compared with hydro-electric, costing from $200 to $250 per kilowatt ($150 to $187 per horse-power).

Capital and Operating Costs of Steam Plant

Mr. Lewis B. Stillwell states that, in 1916, it was estimated that a steam plant, to generate 50,000 kilowatts (66,700 h.p.) could be constructed for $3,185,000, or nearly $64 per kilowatt ($48 per horse-power). Allowing 12 per cent for interest, amortization, and taxes, the cost per k.w.-hour would

be·53 cents, assuming a 50 per cent load factor and coal at $3 per ton. To compete with such steam plant, he estimates that, assuming capital charges of 15 per cent per annum, an investment in a hydro-electric plant of $130 per kilowatt ($98 per horse-power) would be justifiable.

The foregoing, of course, rests upon the assumption, for the hydro-electric plant, that the flow of the stream will permit developing the full amount of power throughout the year. If a steam plant must be provided and operated as an auxiliary during the low stages, the justifiable investment in a hydro-electric plant, cited above, would be reduced by the cost of the steam plant. In addition, the capitalized value of the maintenance and operating charges of the steam plant must also be deducted.

The large investment of capital in a water-power plant carries with it a very heavy interest charge. Mr. Gano Dunn made an analysis* of the gross operating expenses of a typical steam electric and typical hydro-electric station of 20,000 horse-power each. The investigation disclosed that, while the cost of coal formed 48.9 per cent of the gross operating expenses of the steam-electric plant, and bond interest, 19 per cent, the bond interest of the hydro-electric constituted 77.4 per cent of the gross.

Obviously, that heavy charge, absorbing over three-fourths of the operating expenses, is incurred whether the plant be operated to full capacity—to half capacity—or whether it be idle. Failure to ascertain or to recognize this important factor is one of the commonest causes of the economic failure of water-power plants.

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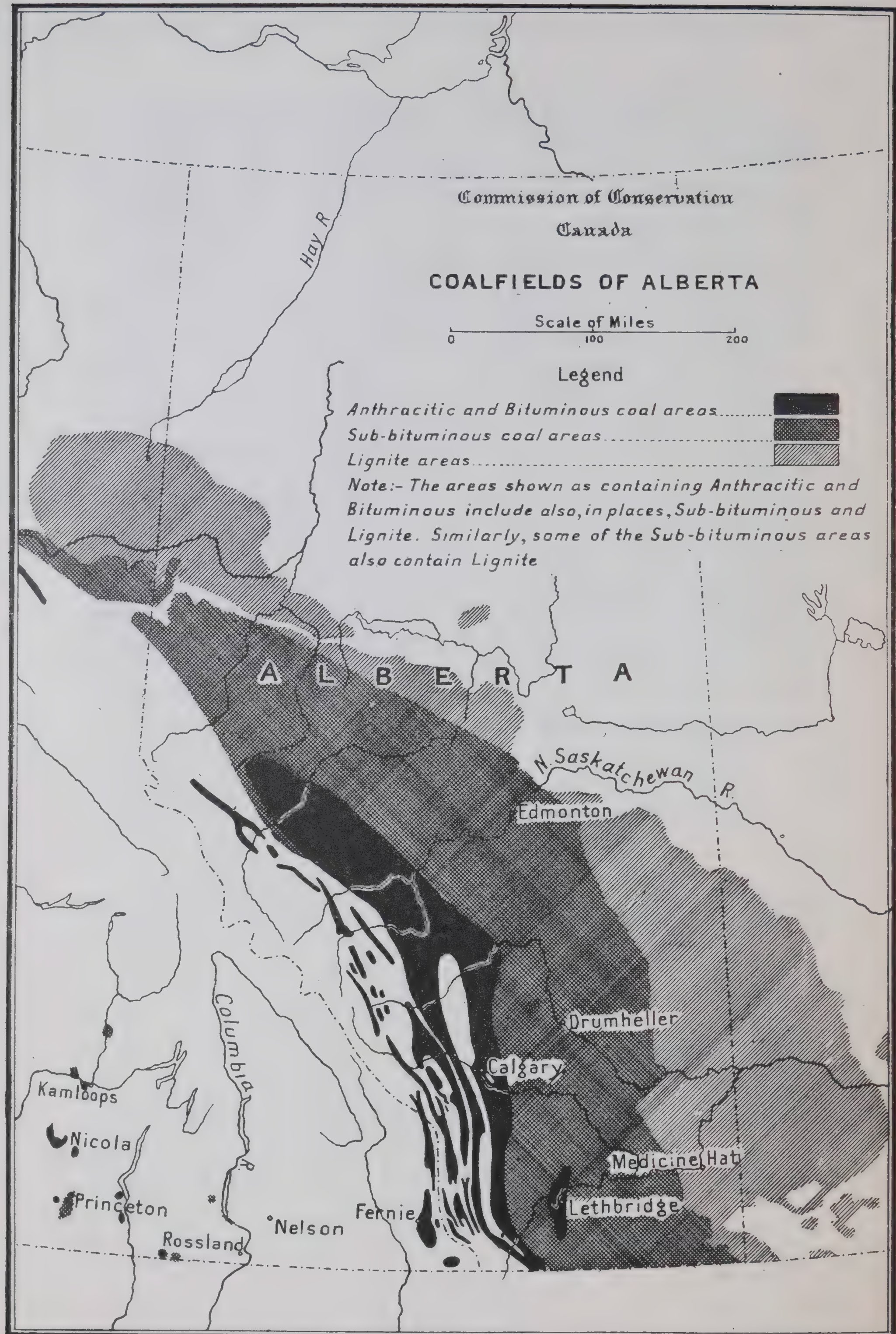
* Mr. Dunn's analysis is as follows:
Unit Analysis of Gross Operating Expenses in Typical Steam-Electric and Hydro-Electric Station of the Same Capacity, 20,000 h.p., Annual Load Factor 50 per cent and Producing Power at the Same Cost. Coal $3.25 per Ton Delivered. Returns to Capital 7%.

——	Steam station, per cent of total gross operating expenses.	Hydro-electric station, per cent of total gross operating expenses.
Administration	4·0	4·0
Ordinary operating expenses (except coal)	10·6	4·8
Coal	48·9	....
Taxes and insurance	6·7	2·8
Depreciation	10·8	11·0
Bond interest	19·0	77·4
Total	100·0	100·0

Water-power Handicapped

Mr. Julian Smith, Chief Engineer and Vice President, Shawinigan Water and Power Co., Shawinigan, Que., states that the capital cost of a water-power plant is twice that of a steam plant, and that, if this cost is high because of high labour costs, the water-power plant is handicapped forever. He is of the opinion that, for many years, steam plants will be of primary importance and water-power plants of secondary importance, but excludes from this dictum the great powers of the Niagara and the St. Lawrence, which have great inherent and special advantages.

It should be emphasized that the steam plant, as compared with the hydro-electric, occupies to-day a much more advantageous position than it did, say, fifteen years ago. The hydro-electric plant had a high initial efficiency, and, in that period, has only made an advance of, say, 10 per cent. In addition, it has reached such a high efficiency that it is not susceptible of considerable improvement. Its capital cost has increased owing to the increased cost of labour and materials. On the other hand, the initial low efficiency of the steam plant offered ample scope for improvement and the lower first cost is due to the development of the steam turbine. It is also susceptible of further improvement and that improvement may be confidently anticipated. The capital cost of the steam plant is only one-half what it was fifteen years ago, and the consumption of coal has been reduced by from one-third to one-half.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COALFIELDS OF ALBERTA
Scale of Miles
0
100
200
Legend
Anthracitic and Bituminous coal areas
Sub-bituminous coal areas
Lignite areas
Note:- The areas shown as containing Anthracitic and Bituminous include also, in places, Sub-bituminous and Lignite. Similarly, some of the Sub-bituminous areas also contain Lignite
Hay R.
ALBERTA
N. Saskatchewan R.
Edmonton
Drumheller
Calgary
Medicine Hat
Lethbridge
Columbia R.
Kamloops
Nicola
Princeton
Rossland
Nelson
Fernie

COAL

Alberta contains 87 per cent of the coal in Canada, but the estimate in the *Coal Resources of the World* states that 82 per cent of the coal in that province is lignite or sub-bituminous. Practically the whole of the settled portion of the province is underlain by this valuable fuel, and the statements in the preceding paragraphs respecting the relative costs of steam-electric and hydro-electric power, indicate the desirability of investigating the economics of steam-electric power generated at *super-power* stations and transmitted to the municipalities within easy transmission distance, say 100 miles or more.

Transmission Lines from Central Stations

On the map, circles have been drawn (pp. 16 and 17) with a radius of 100 miles. The centres of these circles are only suggestive, and Lethbridge, Drumheller and Edmonton (or Clover Bar) were selected as being central points of maximum production of coal. That the Lethbridge and Edmonton circles do not touch the eastern boundary of the province is unimportant, as the transmission is not limited to a distance of 100 miles, the Ontario Hydro-Electric transmission line extending from Niagara to Windsor, a distance of 230 miles.

The larger coal-mining centres have been selected because such large super-power plants give unusual opportunities for economies. For instance, they can use coal which, under ordinary circumstances, would be left in the mine as it would be unprofitable to bring it to the surface. As an example of such economy, the Alliance Power Company state that "by burning lignite slack" they "have succeeded in reducing the coal bill in the Edmonton, Alta., power-house from $165,000 a year, to $75,000"; also, that, if an automatic stoker were devised which would "respond and evaporate the necessary water in the boilers to handle the overload at peak," much better results could be obtained. It is well within the mark to state that the coal that is being wasted in the 240 or 250 coal mines in Alberta which are now being operated in a small way, would, if properly utilized, generate all the power now being used in the province.

Other economies are to be looked for along the many lines of research now being conducted with the object of reclaiming commercial by-products, much after the manner in which the large municipal gas companies conduct their operations.

The *average* total capacity of the hydro-electric central station plants in Alberta is 7,995 h.p.; of the steam-electric, 1,233 h.p., and of the internal-combustion-electric, 222 h.p.

A turbo-generator of 80,000 horse-power is in operation in New York at the present time. Obviously, generators of such size, installed in super-power stations at the coal mines, would show remarkable economies as compared with the numerous isolated plants which would be supplanted by them, the most important being the saving of coal and its transportation. As compared with existing plants, there would be a notable saving in coal consumption, transportation, man-power, etc.

Present Power Development

The Census and Statistics Branch estimates the total power used in the "principal industries" of Alberta at 100,000 h.p. It is evident that *one giant unit of 80,000 h.p. such as is now in operation in a street railway power-house in New York, could supply nearly the whole of the present power consumption of the principal industries of the Province of Alberta.*

The inter-connection of power systems also offers opportunities for fuel economy, particularly if they include hydro-electric systems which have a surplus output during the high-water season. Such inter-connection also permits the increase of the load factor and the reduction of the peaks inasmuch as the loads carried by different systems do not coincide. Thus, inter-connection permits the maximum use of water-power and the increase of the average load factor. Again, if there are uneconomical central stations in the system, they may be held in reserve and only put in operation when necessary to carry a high load. It is estimated that, in 1918, inter-connection and closing uneconomical plants in the United States saved 540,000 tons of coal.

As indicated above, it is not sufficient to devote attention solely to increasing the efficiency of the generating machinery, but every effort must be directed to increasing the efficiency of the whole system.

It should be emphasized that, in indicating the numerous advantages of super-power stations, it is not urged that existing organizations be ruthlessly treated, but that they should be treated with fairness and justice, and should be so welded into the system as to yield the maximum of output consistent with economy. Study of such included systems would permit their operation in a way that would reduce to a minimum the losses due to their relative lack of efficiency.

Market for Power

As it has already been stated that the cost of hydro-electric power decreases with the increase in the load factor, it is obvious that a market which will provide a high load factor is extremely desirable. Electro-chemical work gives a load factor frequently as high as 90 per cent. Under this

head is included the electrolytic alkali industry, the products of which are: caustic soda, used in the manufacture of soap, mercerizing cotton, etc.,; metallic sodium, used as a basis of cyanide; chlorates, used in the manufacture of matches, explosives, etc.; hypochlorites, for bleaching and sterilizing water; chlorine, a sterilizer and for the formation of a bleach. The chief products of the electric furnace consist of abrasives, graphite, silicon, ferro-alloys, such as ferro-chrome, ferro-silicon, ferro-tungsten, etc., which are used in the steel industry; calcium carbide, used in the manufacture of cyanamide and acetylene.

Increasing Cost of Niagara Power

To attract industries to an electrolytic plant, certain advantages must be presented, such as cheap power, transportation facilities, large market, etc. The question naturally arises: What is cheap power? About 15 years ago the Ontario Hydro-Electric Commission closed a 10-year contract for a block of power up to 100,000 h.p. at $9 per horse-power-year. The present rate for new contracts is stated to be about $20 per horse-power-year, which demonstrates that Niagara power is no longer 'bargain' power. In addition to paying $20, the purchaser of Niagara high-tension alternating current must also provide transformers, etc., which increases the cost to a figure which approximates to the cost of steam-power in New York city, using the smaller size and cheaper coal.

Fixation of Nitrogen

For a very large plant generating cheap electric energy, the possibilities of fixation of atmospheric nitrogen for fertilizing purposes have been urged. There are two processes, namely, oxidation of nitrogen in the electric arc, and the conversion of calcium carbide into cyanamide. A large plant devoted to the cyanamide industry has already been established at Niagara Falls, Ont. Some engineers have stated that, if a very large amount of power were available in Eastern Canada at a very low figure, say, $12* per horse-power-year, a great nitrogen fixation industry could be developed. Other engineers, however, state, that, for this purpose, power should not cost more than $5 or $6. The portion of the Alberta product of such an industry that was marketed in Western Canada would, of course, be in an advantageous position, but transportation charges to eastern Canada or the eastern United

*The plant of the American Nitrogen Products Company is situated near the Lake Buntzen hydro-electric plant of the British Columbia Electric Co., on the North arm of Burrard inlet and near Vancouver, B.C. The American Nitrogen Products Company is manufacturing sodium nitrate, ammonium nitrite and nitric acid. The ammonium nitrite is used in the manufacture of dyes and the nitric acid has been sold to the British Government for use in the manufacture of explosives. It is reported that the American Nitrogen Products Company is paying $12 per horse-power-year for the electric energy it consumes. At the present time the B. C. Electric has a considerable amount of surplus power and can afford to sell its surplus at a very low rate. In the plant of the Nitrogen Products Co. the nitrogen is oxidized in the electric arc.

States would be higher than from points nearer those markets.

Mr. Lawrence Addicks is of the opinion that a mammoth steam plant established close to a coal mine and with a sufficient and suitable supply of water for boiler feed and condensing, "could give a lower power cost than is now obtainable at Niagara."*

Summing up: The foregoing discussion demonstrates that modern development in the mechanical and industrial arts has disclosed the fact that coal is now a serious competitor of all other kinds of power, including hydro-electric. Alberta, therefore, with its great coal resources, should most carefully consider the possibilities of utilizing its coal along the lines suggested by the comments already made.

Railway Electrification

In view of the importance of the subject of railway electrification, a brief reference to the subject will not be out of place.

While extension of the electrification of steam railways in the near future is probable, there are several factors in the problem which render it extremely unlikely that very considerable mileage will be electrified.

Mr. W. F. Tye, late Chief Engineer, Canadian Pacific railway, has contrasted the advantages and disadvantages of the electric and the steam locomotive. He points out that the advantages of haulage by electric locomotive, as compared with the steam locomotive, are numerous. The cost of maintenance of an electric locomotive is much less; it does not require to be sent into the roundhouse for cleaning, etc., at the end of a run; two or more can be operated together without loss of power; at the top of a long grade the electric retains its full power; on long descending grades, regenerative braking returns the energy of the train into the trolley line or third rail, and, in severe winter weather, the train load need not be reduced.

Capital Cost of Railway Electrification

On the other hand, electrification would necessitate raising large amounts of capital; railways are not finding that an easy operation, and interest charges are much higher than in pre-war days. Electrification of all lines would require the construction of hydro-electric and steam-electric plants. The railway load is a fluctuating one, varying from hour to hour and from day to day, and the numerous plants which had no market other than the railway load would have a low load factor, which, as already pointed out, means expensive power. Again, failure of portions of the electric installation, such as a break in the transmission, may tie up a considerable mileage.

Mr. W. F. Tye has stated that no road in Canada, except, possibly,

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* For data *re* cost of transmission lines, see p. 23.

the Canadian Pacific, is in a position financially to contemplate large capital expenditures, and that he understands the " Canadian Pacific has not, as yet, found a place where the traffic is sufficiently dense to justify the cost of installation of electric traction."*

The possibility of the haulage of great tonnage by electric locomotives has been demonstrated, but I understand that serious trouble is now being experienced owing to the fact that the ordinary railway road bed will not stand up under the heavy braking of trains and other exacting conditions of physical operation.

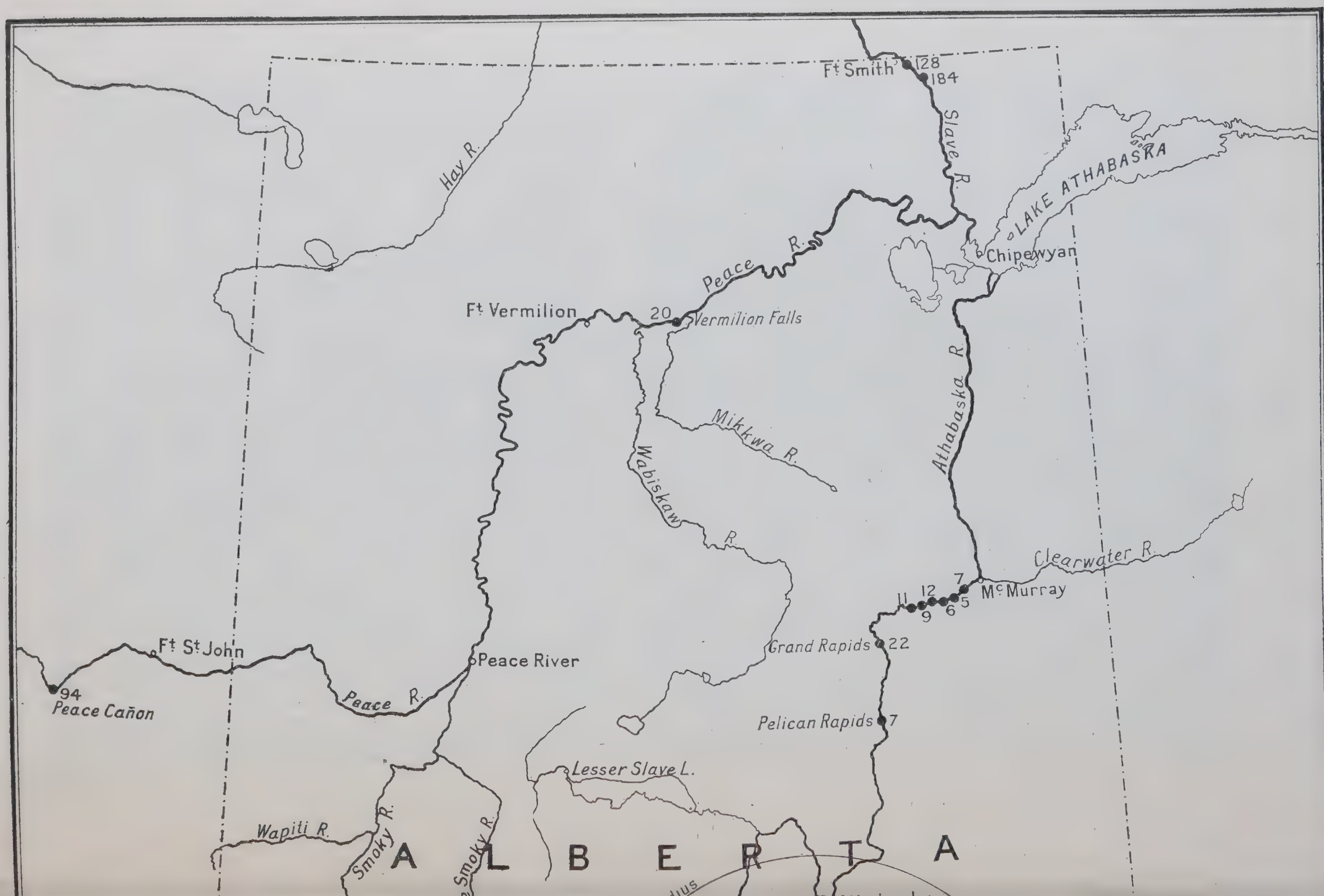
Reference is frequently made to the electrification of the Chicago, Milwaukee and St. Paul R.R. as indicating the economic practicability of railway electrification. It must be borne in mind, however, that, in the vicinity of that railway, were two powers with high heads and on a great river, the Missouri; that these powers were already developed, and that they were carrying the full burden of their bond interest. Obviously, a customer who would take a block of 60,000 h.p. might convert a losing enterprise into a paying one, and the company could afford to give such customer a low rate. On the other hand, I am informed that, when the Canadian Pacific decided to improve conditions in the heavy grade between Hector and Field, B.C., they decided that it would be better to spend $2,000,000 on 7 or 8 miles of new line than to electrify the existing line.

Industries in Alberta

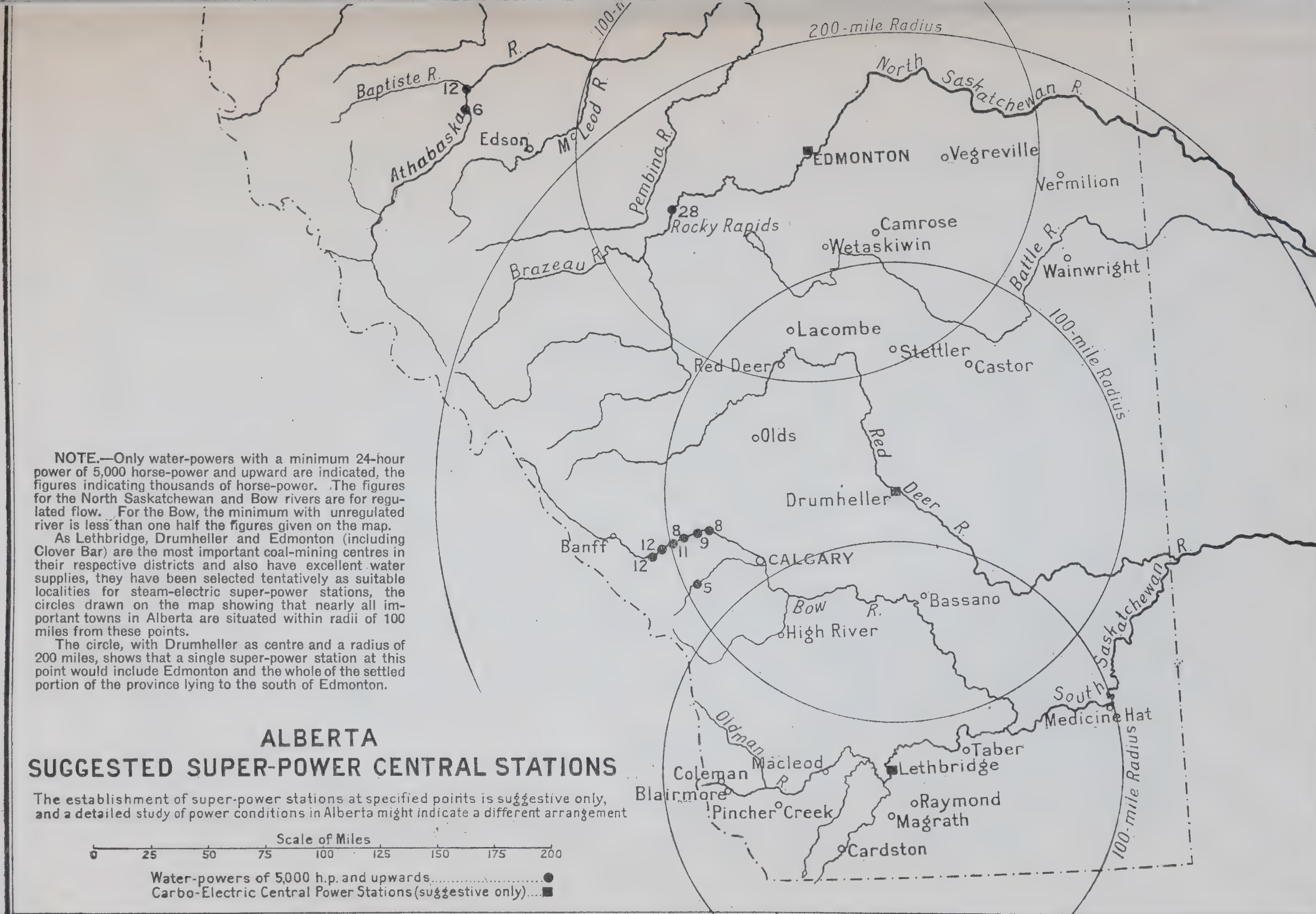
At the present time, there are, in Alberta, four hydro-electric central station plants with an aggregate capacity of 31,980 h.p.; 42 steam-electric plants with 51,805 h.p. capacity, and 6 internal-combustion plants of 1,332 h.p. capacity. According to the table on page 18, supplied by the Census and Statistics branch, the principal industries in Alberta include 272 plants. These plants utilize 238 steam engines, with an aggregate of 63,211 h.p.; 9 gas engines of 527 h.p.; 63 gasolene engines of 584 h.p.; 17 water wheels of 32,920 h.p.; 114 electric motors of 1,392 h.p.; and ' other power ' aggregating 662 h.p. Grand total of power thus used in Alberta, 99,296 h.p., exclusive of motors supplied from plants which appear under their own prime-movers, such as steam, water-wheels, etc., and other rented power. This figure, practically 100,000 horse-power, is only a statistic of the *principal* industries. Nevertheless, it demonstrates that two gigantic 80,000 h.p. steam turbo-generators, such as are now in operation in New York, could produce more power than is now in use in the whole of the province of Alberta.

The table on page 18, prepared by the Census and Statistics Branch, gives the more important power-using industries in Alberta.

* *The Times*, London, states that a rough estimate, based on pre-war figures, showed that electrifying the 24,000 miles of railway in Great Britain would cost about $100,000 per mile.



Hay R.
Ft. Smith
128
184
Slave R.
LAKE ATHABASKA
Chipewyan
Peace R.
Ft. Vermilion
20
Vermilion Falls
Athabaska R.
Mikkwa R.
Wabiskaw R.
Clearwater R.
McMurray
7
12
11
9
6
5
Grand Rapids
22
Pelican Rapids
7
Ft. St. John
Peace River
94
Peace Cañon
Peace R.
Lesser Slave L.
Wapiti R.
Smoky R.
Smoky R.
ALBERTA



NOTE.—Only water-powers with a minimum 24-hour power of 5,000 horse-power and upward are indicated, the figures indicating thousands of horse-power. The figures for the North Saskatchewan and Bow rivers are for regulated flow. For the Bow, the minimum with unregulated river is less than one half the figures given on the map.

As Lethbridge, Drumheller and Edmonton (including Clover Bar) are the most important coal-mining centres in their respective districts and also have excellent water supplies, they have been selected tentatively as suitable localities for steam-electric super-power stations, the circles drawn on the map showing that nearly all important towns in Alberta are situated within radii of 100 miles from these points.

The circle, with Drumheller as centre and a radius of 200 miles, shows that a single super-power station at this point would include Edmonton and the whole of the settled portion of the province lying to the south of Edmonton.

ALBERTA
SUGGESTED SUPER-POWER CENTRAL STATIONS

The establishment of super-power stations at specified points is suggestive only, and a detailed study of power conditions in Alberta might indicate a different arrangement

Scale of Miles

0 25 50 75 100 125 150 175 200

Water-powers of 5,000 h.p. and upwards ●
Carbo-Electric Central Power Stations (suggestive only) ■

CENSUS OF INDUSTRY, 1917. POWER FOR PRINCIPAL INDUSTRIES

ALBERTA

Name of industry.	No. of estab-lish-ments	Power owned														Power rented				Total Power
		Steam engines		Gas engines		Gasolene engines		Water wheels		Water motors		Electric motors run by current-generated by estab-lishment		Other power		Electric motors operated by rented power		Other power		
	No.	No.	H.P.	No.	H.P.	No.	H.P.	No.	H.P.	No.	H.P.	No.	H.P.	No.	H.P.	No.	H.P.	No.	H.P.	
Brick, tile and pottery	10	15	1,338	....	......	2	21	....	......	....	......	....	......	....	......	26	1,135	....	......	2,494
Butter and cheese	73	51	565	....	......	10	78	....	......	....	......	1	3	17	277	69	652	....	......	1,575
Electric light and power	45	57	51,862	....	......	....	......	14	32,850	....	......	....	......	....	......	....	......	....	......	84,712
Flour and grist mill products	61	29	3,385	7	480	47	426	....	......	....	......	18	291	....	......	39	1,794	4	105	6,481
Liquors, malt	5	15	870	....	......	....	......	....	......	....	......	41	300	....	......	146	691	....	......	1,861
Log products (sawmills)	52	49	2,371	....	......	2	28	2	30	....	......	6	120	2	100	....	......	....	......	2,649
Lumber products	20	9	910	2	47	2	31	....	......	....	......	....	......	5	285	44	731	....	......	2,004
Slaughtering and meat packing	6	13	1,910	....	......	....	......	1	40	....	......	48	678	....	......	80	780	....	......	3,408
Totals	272	238	63,211	9	527	63	584	17	32,920	....	......	114	1,392	24	662	404	5,783	4	105	105,184
Less "rented power"	......	....	......	....	......	....	......	....	......	....	......	....	......	....	......	....	......	....	......	5,888
																				99,296

NATURAL GAS

Alberta contains the greatest developed natural gas resources in Canada but it can not be too often stated, nor too strongly stated, that a reservoir of this enormously valuable natural resource, once exhausted, can never be replaced. It is exceedingly difficult, in fact, almost impossible to convince 'the man in the street' that the life of a gas well is limited to a few years at most, no matter what the initial capacity of the well may be. It is axiomatic, therefore, that natural gas should be used where, and when, the maximum benefit to the community will result therefrom. The recent decrease in the flow from the famous Bow Island gas-field, which supplies Calgary, Lethbridge, Macleod and intermediate towns, emphasizes the foregoing in the most forcible manner.

Mr. T. T. Gray states that a large rolling mill may use 5,000,000 feet of gas per day and that this amount would suffice for 9,000 homes, or, say, 45,000 individuals. He says that " It would, therefore, seem reasonable to prohibit by law the selling of natural gas to one consumer at less than one-half the price paid by another consumer, also to prohibit more than a certain fraction of the capacity of the well to be taken, during the early life of the well."

Gas Values Compared

I venture the statement that, if gas is absolutely required for certain uses, and, if the supply of such by process of manufacture involves a cost of say 75 cents per thousand to the consumer, then Alberta natural gas is worth the same figure, if not more, because, when exhausted, it cannot be replaced except at the cost of manufacture in other places.

Up to a recent date, gas sold in Toronto at 75 cents per thousand, the lowest rate for coal gas in any large city in North America. In view of the general increase in prices, the present price, namely, $1.00 per thousand, probably holds the same pre-eminent position as regards cheapness. The *average* price of natural gas in Alberta in 1918, as sold by the producing companies, was only 19 cents per thousand.

The case for Alberta natural gas, however, is even stronger than the foregoing would indicate. Dr. D. B. Dowling's investigations show that the gas supplied to Calgary has a heating value of 895 British thermal units per cubic foot, as compared with only about 500 B.t.u. for coal gas. Therefore, compared on a basis of heating values, the gas supplied to Calgary from the Bow Island field would be worth $1.78 per thousand in Toronto.

The gas from the Dingman No. 2 well, 32 miles southwest of Calgary, is even higher in heating value, averaging 1,015 B.t.u. according to Dr. Dowling. Based on present Toronto prices it would be worth $2.03 per thousand.

On the other hand, if, owing to excessively high pressure or other reasons, it is impossible to store the gas, it is obviously better to use it for any economic purpose to avoid wasting it.

Natural Gas Fields of Alberta

In Alberta, four important gas-fields have been discovered, namely, the Medicine Hat, Bow Island, Viking and Pelican Rapids fields. The gas is derived from the top of the Colorado in the Medicine Hat field, and from sands in the Lower Colorado in the Bow Island and Viking fields.

Three anticlinal arches have been found. These arches however, are so low and diffuse that, owing to the scarcity of natural exposures of rock, it is difficult to trace them.

The first anticline extends from the Sweet Grass hills in Montana, thence northwestward to the Bow river. The Bow Island field is near the axis of this anticline. The second anticline extends northwestward from the Saskatchewan-Alberta boundary in approximate latitude 52°, to Viking. The third anticline crosses the Athabaska river about 20 miles above McMurray and, like the first and second, has a general northwest-and-southeast course.

Medicine Hat Gas-field

In the Medicine Hat gas-field there are 33 wells, with an approximate capacity, open flow, of from 90 million to 92 million cubic feet per day, which is equivalent to about 53 million feet, working capacity, the working capacity of a well being assumed to be 60 per cent of the open-flow capacity. The largest well has been reported to have a capacity of 6 million feet per day. The tested portion of this field has an area of about 30 square miles. The initial rock pressure was about 600 lbs. to the square inch. The gas-sand is found at a depth of from 1,000 to 1,200 feet and is about 900 feet above the Dakota sandstone. This field supplies Medicine Hat, Redcliffe and vicinity.

Bow Island Gas-field

The Bow Island gas-field has a tested area of about 25 square miles; the initial rock pressure was 790 lbs., and the gas-sand was found in the Dakota sandstone and at a depth of from 1,850 to 2,150 feet. This field supplies Macleod, Lethbridge, Calgary, and the intermediate towns by a 16-inch pipe line, 175 miles long. There are 21 wells drilled in this field and the

total daily capacity, open flow, was about 186 million cubic feet. No. 4 well had a capacity of 29 million cubic feet. The well at Foremost, 36 miles south of Bow Island, and on the same anticline, has an estimated open flow of 13 million cubic feet per day. A heavy oil-sand found at Foremost, 920 feet below the gas-sand, suggests a possible source for the gas.

Wide Range of Gas-Fields

Gas has also been found at Langevin, Cassils, Brooks, Sheep Creek, Vegreville, Wetaskiwin, Three Creeks on the Peace river, and at Pelican rapids on the Athabaska.

In the Viking field, gas has been found in the Dakota sandstone at a depth of about 2,350 feet and in the Grand Rapids sandstone at a depth of about 2,200 feet. The tested area is about 12 square miles. There are eight wells in the Viking field, with a total daily capacity of 36 million cubic feet in 24 hours. The average rock pressure is 710 pounds. It is an ethane gas, in which respect it differs from the Bow Island and Medicine Hat gases, which are very dry. This, no doubt, will permit the production of gasolene by absorption as soon as it has been piped and is in use in Edmonton.

In 1918 the production of natural gas in Alberta was 6,744 million cubic feet, valued at $1,299,976, as sold by the producing companies—an *average* price of 19 cents per thousand feet.

PETROLEUM

Though, up to the present time, petroleum in considerable quantities has not been discovered in Alberta, the situation may be summed up as promising.

The great war has demonstrated the enormous value of petroleum and its products, particularly gasolene. The products of petroleum enter into our daily life under the guise of at least 250 different and marketable commodities. It has immeasurably extended and, in many cases, revolutionized transportation on land, in the air, on the sea and below the sea.

Fuel Oil saves Cargo Space

Its use as fuel for fast passenger vessels will, undoubtedly, be much increased in the near future. By changing from coal to oil, the *Mauretania*, during the round trip from Liverpool to New York and return would save 5,000 tons of fuel, reduce the stokehold force from 300 to 30, and would make available for cargo and passengers about 100,000 cubic feet of space, representing an earning value of $50,000 on each round trip. It is highly probable that, during the next few years, all fast Transatlantic steamers will be fitted to burn oil.

REVIEW OF ALBERTA'S POWER

Conservation of Gas Supply Essential

To very briefly recapitulate:—The foregoing is a general survey of Alberta's assets of water-power, of coal, and of natural gas, with a brief reference to the value of petroleum.

Owing to its unique characteristics, its special adaptability for various purposes, and the possibility of its rapid exhaustion, natural gas should be zealously conserved for use in its sphere of greatest efficiency. In my judgment, this sphere is not the development of power on a *wholesale* scale.

The water-powers of Alberta, valuable though they be, are, nevertheless, limited both with respect to magnitude and situation, Owing to low-water conditions, water-power must be augmented by power from other sources.

Coal the Chief Source of Power

Now, the great source to which Alberta must look for power is her coal. During recent years, the great advance made in the art of the production of steam-power is phenomenal. This advancement has given coal, as a prime agency for power development in competition with other prime agencies, almost a premier position. Those interested in the furnishing of power on a wholesale scale in Alberta must make their research into, and selection from, the achievements made in recent years in the field of power produced from coal.

Careful Study of Conditions Necessary

Just one word of caution. The production and sale of power are not the gold mine the uninitiated have too often assumed them to be. Many factors, financial, economical, and physical, have to be properly weighed and co-ordinated. For instance, in the period 1914–15, hydro-electric plants in the United States, with an aggregate capacity of 600,000 h.p., have been absolute financial failures.

Emphatically, it would be far better not to embark in the production of power in Alberta at all than to make the development and incur serious financial loss. Better to proceed cautiously, examine carefully what has been accomplished elsewhere, profit from the knowledge of failures already made; study most carefully whether economic and other conditions in any locality absolutely warrant the furnishing of a supply of power before entering upon any project of power development.

Understand that I am not speaking pessimistically, but, knowing the failures which have followed many power development opera-

tions, a word of warning on this occasion is certainly not out of place. Alberta has the possibilities of extensive power production, and sound judgment exercised with respect to these resources will result in their best conservation and use. It cannot, however, be too strongly urged that the economic aspect of her power problem demands broad vision, an expert study of conditions, present and potential, and the best judgment that is obtainable. With her enormous coal resources, and assuming that the problem is dealt with in a statesmanlike manner, her prospects are as favourable, if not more favourable than any other province in the Dominion.

COST OF TRANSMISSION LINES

Owing to the great advance in cost of labour and material, the costs of transmission lines have greatly increased over those of pre-war conditions. The present approximate costs for some transmission lines in Ontario may representatively be cited as follows:

A main line 'heavy duty' steel tower transmission line, carrying two lines at 110,000 volts, such as the latest type of line used by the Hydro-Electric Power Commission of Ontario between Niagara Falls and Toronto, with 66-feet right-of-way, the equivalent of 4–0 copper conductors, telephone service, and all items of expense, would be about $17,000 per mile.

A 110,000-volt line, single circuit, supported by wood poles, with 66 feet right-of-way, and the equivalent of 1–0 copper conductors, and telephone line, would be about $8,500 per mile. If pole rights alone are secured the cost might be reduced to about $5,500 per mile.

A 44,000-volt, wood-pole line, with steel conductor and telephone line on same poles, could be erected for about $3,000 per mile, but, if there were considerable rock excavation for poles, this cost might easily be doubled.

A 22,000-volt line, carrying one circuit of approximately the equivalent of No. 1 copper conductor and with telephone line, would cost about $3,500 per mile.

Smaller lines of about 4,000 volts, with equivalent of No. 4 copper conductors, have, under present conditions, been built for about $2,000 per mile.

At the present time, a transmission line from Winnipeg to Portage la Prairie is under construction. It will be 60 miles long, of steel tower construction and will have an ultimate capacity of 20,000 k. w. The immediate installation is of one circuit line of No. 0 aluminium cable which is estimated to carry 5,000 k. w., at 66,000 volts with a 3 per cent drop in voltage at Portage la Prairie: or 10,000 k. w. with 15 per cent voltage loss. The second circuit will be installed as soon as the demand for power warrants it. The estimated cost is $4,600 per mile, which includes substations at Winnipeg and Portage la Prairie. As it follows the highway no right-of-way was purchased except at a few points where the line is on private property.

COST DATA OF TRANSMISSION LINES

Line	Year built	Length, miles	Voltage	Cost per mile	Remarks
				$	
Canadian Light and Power Company, Montreal.	1911	27	44,000	11,000	2 circuits of 2–0 copper, steel towers.
Laurentian Power Company, Quebec.	1916	24	50,000	6,875	2 circuits of 1–0 copper, steel towers.
Shawinigan Water & Power Company.	1902–10	550	50,000	1,500	Single circuit, aluminium, wooden poles.
				3,500	2 circuits, aluminium, steel towers.
" " ..	1910	94	100,000	7,500	2 circuits, aluminium, steel towers.
Sherbrooke Municipal	1917	30	45,000	2,334	Single circuit, No. 4 copper, wooden poles.
Hydro-Electric Power Commission. Niagara system.	1907–13	325	110,000	14,000	2 circuits 4–0 and 3–0 copper and equivalent aluminium, steel towers.
" " ..	1907–13	765	26,400 and under.	2,200	Single circuit, aluminium and copper, wooden poles.
				3,000	2 circuits, aluminium and copper, wooden poles.
Muskoka system...	1915	26	22,000	2,025	Single circuit, No. 2 aluminium, wooden poles.
St. Lawrence system.	1913–15	60	26,400	2,458	Single circuit of 3–0 aluminium, wooden poles.
Kamloops Municipal.	1916	42	44,000	1,667	Single circuit of No. 2, aluminium, wooden poles.
West Kootenay Power and Light Company, Rossland.	1897–1905	170	60,000	4,000	Single circuit, 92,000 c.m. copper, wooden poles.
" " ..	....	32	20,000	2,000	2 circuits, No. 2 copper, wooden poles.

LINE LOSSES

Name of company	Termini	Voltage at generating end	Distance	Loss per cent
			Miles	
Shawinigan Co.......	Grand'mère to Montreal...	100,000	94	10
Can. Light & Power Co.	St. Timothée to Montreal..	44,000	27	8
Laurentian Power Co.	St. Féréol to Montmorency	50,000	24	5
Sherbrooke Municipal	Weedon to Sherbrooke.....	45,000	30	13
Hydro-Electric Power Com.	Napanee to Kingston......	44,000	30	10
Toronto Power Co....	Niagara Falls to Toronto..	60,000	80	20
Dom. Power & Traction Co.	Power Glen to Hamilton..	44,000	33	6
Winnipeg Municipal..	Pte. du Bois to Winnipeg..	66,000	78	20
Calgary Power Co....	Kananaskis to Calgary....	50,000	50	7½
West Kootenay Power and Light Co.	Bonnington to Greenwood.	60,000	82	10
B. C. Electric Ry. Co.	Jordan plant to Victoria..	60,000	43	16

NOTE RESPECTING NITROGEN FIXATION WITH SPECIAL REFERENCE TO THE UTILIZATION OF WATER-POWER

By L. G. Denis, E.E.

General

A striking characteristic in the manufacture of air nitrates is the multitude of processes in actual commercial use. In considering a prospective undertaking, therefore, the question of selecting the most advantageous method is probably the most important. In this connection, a great many articles and papers have appeared in the technical press and society proceedings dealing with the subject in a thorough manner. Unfortunately, however, each author, while apparently treating the subject in a general way, usually emphasises in no uncertain way the particular method which he is either using himself or is interested in having others use. Few papers, if any, treat the merits of the various methods impartially. The advantage of one method over another is really a question of local and of cognate conditions.

The known processes may be grouped under three general methods: (1) the *arc* or direct *oxidation*, in which the principal agent used is electric energy; (2) processes where electric energy and chemical reaction are combined to obtain the final product, and where these agents are of nearly equal importance. One of the processes coming under this head is the well-known cyanamide process used in the large factory at Niagara Falls, Ontario; (3) processes, such as the synthetic ammonia process, which are practically all chemical, and in which electric energy is of very little importance.

From the above it may be seen, therefore, that the most suitable process to adopt is largely a question of weighing the cost of electric energy against that of various materials, such as lime, coke, etc., and of the additional skilled labour necessitated by the partly or wholly chemical process.

L. L. Summers, in a paper before the American Institute of Electrical Engineers, gave the following comparison of power requirements for the various methods:

Direct oxidizing of atmospheric nitrogen, 5 per cent efficiency, yield at 550 kg. per k.w.-year, requires per kg. of N....................	65 k.w. hrs.
Cyanamide process, 66 per cent efficiency in carbide, 1 per cent loss in heating to combine with N. (also preparation of N.) requires per kg. of N..................................	16·6 "

Aluminium nitride, using coal to heat products to temperature of reaction, requires per kg. of N.	12 k.w. hrs.
Catalytic method of combining N. and H. to form ammonia (also preparation N. and H., refrigeration, and compression to 200 atmospheres) requires per kg. of N..............	1·5 " *

In the same paper Mr. Summers states that "one of the chief interests in the chemical utilization of electrical energy is centred in the possibilities of off-peak or off-season loads, as American plants generally have a certain proportion of power which can be disposed of to better advantage than selling the entire output as low-priced power to chemical industries. This off-peak power is difficult to utilize in furnace work, where the cooling of the furnace and its charge is an important factor, both from the standpoint of cost and of output; and again, adjustments may be so disturbed from an interrupted output as to be absolutely impracticable."

He suggests as a possible solution for off-peak utilization the adoption of some system where fuel is also utilized and the radiation losses are not excessive under conditions of banked fire when the electric portion of the heat energy is not in use. He is of the opinion that "some of these combination processes may promise a solution of the off-peak load situation more attractive than the straight electric furnace."

Electric Arc Process

Referring particularly to the arc process to produce nitric acid, Mr. Summers makes the below estimate, based on the assumption that nitric acid is selling for $60 per ton. If the yield is 550 kilogrammes of acid per kilowatt-year, he estimates that the manufacturer cannot pay more than $15 per k.w.-year ($11.25 per horse-power-year) for his electric energy. He assumes that labour and repairs will cost $10 per ton of acid; that the interest charge will be $8 per kilowatt-year and general expenses $5 per k.w.-year.

Mr. E. K. Scott,† in a paper considering "adequately and sympathetically" the merits of the arc flame process for making nitric acid, compares it with the cyanamide process. He gives a tabular statement showing that the arc flame method only requires one factory against three for the cyanamide process; two operations against seventeen; two kinds of skilled labour against eight kinds for the cyanamide; while the raw materials and renewals are tabulated thus:

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* *Proceedings, American Institute of Electrical Engineers*, March, 1915, pp. 609-610.
† *Ibid*, June, 1918, pp. 957-962.

Cyanamide	*Arc Flame*
1. Lime	1. Air
2. Coke	2. Water
3. Carbon electrodes in carbide furnaces	3. Metal electrodes
4. Carbon resisters in cyanamide retorts	
5. Pure nitrogen	
6. Superheated steam	
7. Air	
8. Water	

Mr. C. P. Steinmetz has stated that:*

> "The final solution of the nitrate problem is to be found in the arc flame process or direct process................"
>
> "I agree that the direct process requires more electric power than the cyanamide process, for instance, but, at the same time, there are other processes, like the ammonia process, which require no electric power, and the reason why the cyanamide process requires much less power is that, of the various operations, only a very small part, the first quarter, is carried out electrically. We may put the statement the other way and say that, in the direct process, nothing but electric power is required, and all the work is done by electric power, while in the other, the indirect process, electric power plays only a secondary part, or no part at all.
>
> "The present situation, as we all realize, is peculiar, that we have to face an emergency. It is not a question whether the one process is better or more economical than the other one, but the question is, first, which process can be brought into operation on a larger scale in the quickest manner...
>
> "Of all the methods of nitrification the only one which is capable of efficient intermittent operation is the arc process, or direct process. The arc is equally as efficient in the second or milli-second after it is started as it is after continuous operation for days. That is not the case, however, with the cyanamide process, where even a very short time interruption means freezing of the carbide furnace and serious loss and interruption...
>
> "We hear and have definite information that the Norwegian arc process nitrate plants are commercially successful and profitable, but we also hear that the conditions there are peculiar, such as cannot be found in our country, and the peculiarity is claimed to be the very low cost of power. That is not strictly true in all respects, because off-peak power here can be secured cheaper in many cases than the Norwegian power."

Referring to the future possibilities of the arc process through new discoveries to increase its efficiency, Mr. Steinmetz states that:†

> "The present efficiency is from 60 to 80 grams per kilowatt-hour. The theoretical efficiency of nitric oxide pro-

* *Proceedings, American Institute of Electrical Engineers*, June, 27, 1918, pp. 975-976.
†*Ibid*, p. 978.

duction is 2,500 grams of NO_3H per kilowatt-hour, so that the present best results are an efficiency of 3 per cent.

"You can realize, therefore, the vast possibilities there are in increasing the efficiency, and if, at an efficiency of only 3 per cent, the process has become commercial under favourable conditions, we can see that there are possibilities in this method."

Mr. E. K. Scott,* commenting on the economic size of factory, states that a convenient size of air nitrate factory is one to take about 10,000 k.w., but, of course, the larger the factory the lower the cost per kilowatt of plant installed, and the lower the working cost and of overhead charges per unit of finished product.

The ordinary standard voltages of 5,500 and 6,600 and periodicities of 25 and 60 per second, are suitable, so it is not necessary to install special generating machinery. The energy can be tapped from a general transmission network, although there are advantages in having the factory near to the power house.

Cyanamide Process

In a paper on the *Cyanamide Process*, F. S. Washburn, President of the American Cyanamide Company of Niagara Falls, Ont., states that:†

"Cyanamide is the only artificial nitrogenous product which can be used directly in agricultural service and it is well adapted to the cheap production of an ammonium phosphate which is of even more service in agriculture. Agricultural uses will predominate over industrial, especially as these can be well served by the nitric acid and ammonia processes. Phosphate rock is mined only in Florida and Tennessee, and the cost of transportation to the nitrogen works will be the governing factor in the location of the latter. The plant must be on a waterway near a cheaply-developed water-power. Much of the product will be distributed by the empty returning boats and the cost of such transportation of the finished product will largely be only the expense of handling."

In 1916, Mr. Washburn stated‡ that the world's yearly fixation of nitrogen by the arc process is some 32,000 net tons, compared to 200,000 tons by the cyanamide process. The former process is practically confined to Norway, while the latter has been applied in Norway, Sweden, Germany, Austria, France, Japan, and Canada.

There is employed in the world's nitrogen fixation industry 1,000,000 continuous horse-power, and the distribution is as follows:

Canada	30,000 h.p.
Germany	350,000 h.p.
Norway	450,000 h.p.
Dalmatia, Italy, Switzerland, Japan, France	150,000 h.p.
	980,000 h.p.

* *Canadian Chemical Journal*, Nov., 1918, p. 279.
† *Engineering News*, March 18, 1915, p. 557.
‡ *General Electric Review*, Feb., 1917, p. 159.

In describing the various steps in the cyanamide process, Mr. Washburn states that the greatest heat and the greatest cold obtainable are utilized in making cyanamide. By the intense heat of the electric furnace (6,000°F.) lime and coke are fused together to make calcium carbide. This is powdered and placed in large drumlike ovens and then brought by electricity to a white heat. In the meantime wonderful machines are making liquid air by compressing and cooling over and over again clear, pure air until at 380° *below* zero the air liquefies. Air is four-fifths nitrogen and one-fifth oxygen. When the liquid air is warmed a little only pure nitrogen gas is given off. This is pumped into the drum-shaped ovens containing the white-hot carbide, by which it is absorbed and by which it is permanently fixed. The product, cyanamide, when cooled, ground, and processed with special machinery, is suitable for use as a fertilizer."*

H. Freeman, also of the American Cyanamide Company of Niagara Falls, Ont., in an address on *Nitrogen and its Compounds*, stated that.†

> "The cyanamide process and the arc process require considerable amounts of power for their commercial operation, the arc process requiring five times the amount of power that the cyanamide process demands in order to produce the same quantity of fixed nitrogen.........................
>
> "The cyanamide process is the best adapted for the conditions and requirements of North America."

United States Government Plant

In 1917, owing principally to war requirements, the United States government decided to undertake the manufacture of ammonia and nitric acid, and, for this purpose, adapted the synthetic-ammonia process which would not involve the use of water-power. This choice, however, as suggested in Mr. Steinmetz's statement quoted above, may have been influenced by considering which process could be brought into operation on a large scale in the quickest manner. Among the recommendations of the Nitrate Committee which were approved by the United States Secretary of War in regard to the government plant, the following may be noted:‡

> "(1) That the Government negotiate with the General Chemical Co. for the use of its process; (2) that \$3,000,000 be used to build a plant to produce 60,000 lb. of ammonia per day and that it be located preferably in southwestern Virginia; (3) that at least \$600,000 be used for building an ammonia-oxidation plant producing the equivalent of 24,000 lb. of 100% nitric acid per day..........................(8) that more extensive installation of fixation processes or water-power development be postponed until the recommended plants are in operation or further need arises."

**Canadian Chemical Journal*, March, 1918, p. 75.
†*Canadian Chemical Journal*, April, 1918, p. 88-89.
**Engineering News-Record*, Sept 6, 1917, pp. 475-476.

Conclusions

The following conclusions regarding the merits of the various processes of the air-nitrate industry may be based upon the foregoing:

(1) The *direct* or *arc* process offers most advantages where very cheap hydro-electric energy is available. Owing to its flexibility to intentional interruptions it is well suited for off-peak loads. With regard to the amount of energy consumed this process is, as yet, very inefficient, but the consequent wide gap before theoretical perfection can be approached gives much hope that future discoveries will improve its efficiency.

(2) The *indirect* or *cyanamide* process has most advantages where the cost of energy is reasonably low, say in the neighbourhood of $10 to $12 per horse-power per year. The large plant located in Canada, at Niagara Falls, Ont., and using some 30,000 h.p., has been operating with this process for a number of years.

(3) In localities where the cost of energy is high and offers no special inducement, purely chemical processes, such as the synthetic ammonia process, may present the maximum of advantage.